DFW

Patent Application

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICANTS:	Choo et al.	EXAMINER: Tentoni, Leo B.
SERIAL NO.:	10/667,515	GROUP ART UNIT: 1732
FILED:	September 23, 2003	DOCKET: 6192.0261.D1 (8054L-206T)
FOR:	**METHOD AND APPARATUS FOR CUTTING A NON-METALLIC SUBSTRATE USING A LASER BEAM**	

MAIL STOP AF
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

SUBMISSION OF CERTIFIED TRANSLATION

Examiner:

Please consider the attached certified English translation of the priority document corresponding to the above-identified U.S. patent application. The translation is being provided in response to the Final Office Action of November 23, 2005, to antidate Xuan et al. (USPN 6,744,009), wherein Xuan was first cited in said Final Office Action.

Entry of the certified English translation is respectfully urged.

Respectfully submitted,

By:

Nathaniel T. Wallace
Reg. No. 48,909
Attorney for Applicant(s)

F. CHAU & ASSOCIATES, LLC
130 Woodbury Road
Woodbury, New York 11797
TEL: (516) 692-8888
FAX: (516) 692-8889

CERTIFICATE OF MAILING UNDER 37 C.F.R. §1.8(a)

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail, postpaid in an envelope, addressed to the: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on April 5, 2006.

Dated: April 5, 2006

Nathaniel T. Wallace

PTO/SB/21 (09-04)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMITTAL FORM

(to be used for all correspondence after initial filing)

Application Number	10/667,515
Filing Date	09/23/2003
First Named Inventor	DAE-HO CHOO
Art Unit	1732
Examiner Name	Tentoni, Leo B.
Attorney Docket Number	8054L-206T
Total Number of Pages in This Submission	29

ENCLOSURES *(Check all that apply)*

- ☐ Fee Transmittal Form
  - ☐ Fee Attached
- ☐ Amendment/Reply
  - ☐ After Final
  - ☐ Affidavits/declaration(s)
- ☐ Extension of Time Request
- ☐ Express Abandonment Request
- ☐ Information Disclosure Statement
- ☑ Certified Copy of Priority Document(s)
- ☐ Reply to Missing Parts/ Incomplete Application
  - ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53
- ☐ Drawing(s)
- ☐ Licensing-related Papers
- ☐ Petition
- ☐ Petition to Convert to a Provisional Application
- ☐ Power of Attorney, Revocation Change of Correspondence Address
- ☐ Terminal Disclaimer
- ☐ Request for Refund
- ☐ CD, Number of CD(s) ____________
  - ☐ Landscape Table on CD
- ☐ After Allowance Communication to TC
- ☐ Appeal Communication to Board of Appeals and Interferences
- ☐ Appeal Communication to TC **(Appeal Notice, Brief, Reply Brief)**
- ☐ Proprietary Information
- ☐ Status Letter
- ☐ Other Enclosure(s) (please Identify below):

Remarks

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT

Firm Name	F. CHAU & ASSOCIATES, LLC		
Signature			
Printed name	NATHANIEL T. WALLACE		
Date	April 5, 2006	Reg. No.	48,909

CERTIFICATE OF TRANSMISSION/MAILING

I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:

Signature			
Typed or printed name	NATHANIEL T. WALLACE	Date	April 5, 2006

DECLARATION

I, Young Woo Park, Korean Patent Attorney of 5F, Seil Building, 727-13, Yoksam-dong, Gangnam-gu, Seoul, Korea do hereby solemnly and sincerely declare as follows:

1. That I am well acquainted with the English and Korean languages.
2. That the following is a correct translation into English of the accompanying certified copy of a Korean Patent Application No. 2001-27677

and I make the solemn declaration conscientiously believing the same to be true.

Seoul, February 20, 2006

Young-Woo Park

Young-Woo PARK

THE KOREAN INDUSTRIAL PROPERTY OFFICE

This is to certify that annexed hereto is a true copy from the records of the Korean Industrial Property Office of the following application as filed.

Application Number : Patent Application No. 2001-27677

Date of Application : May 21, 2001

Applicant : Samsung Electronics Co., Ltd.

COMMISSIONER

PATENT APPLICATION

Applicant : Name: Samsung Electronics Co., Ltd.
(Representative: Jong-Yong YUN)

Address : 416 Maetan-dong, Yoengtong-gu, Suwon-city,
Kyungki-do, Republic of Korea

Agent(s) : Young-Woo PARK

Inventor(s) : Name : Dae-Ho CHOO

: Address : 223-1803 Byeocksan Apt., Yeongtong-dong,
Paldal-gu, Suwon-si, Gyeonggi-do, Korea

Inventor(s) : Name : Baek-Kyun JEONG

: Address :104-302 Hansung Apt., #380, Gugal-ri, Giheung-eup, Yongin-si, Gyeonggi-do, Korea

Inventor(s) : Name :Hyung-Woo NAM

:Address :105-401 Dongbo Apt., #691, Pungdeockcheon-ri,
AddressSuji-eup, Yongin-si, Gyeonggi-do, Korea

Title of the Invention : METHOD AND APPARATUS FOR CUTTING A NONMETTALIC SUBSTRATE USING A LASER BEAM

To the COMMISSIONER

[ABSTRACT DOCUMENT]

[ABSTRACT]

A method and an apparatus for cutting a non-metallic substrate by a laser are disclosed. In the method and apparatus, a first laser beam for breaking molecular bonds of the non-metallic substrate material is scanned on a cutting path formed on the non-metallic substrate to form a scribe line having a crack in a desired depth. Then, a second laser beam is scanned along a scanning path of the first laser beam to propagate the crack in a depth direction of the substrate and completely separate the non-metallic substrate. Since the cutting speed can be controlled by the speed of the first laser beam, the cutting speed can be increased as well as the cutting speed can be facilely controlled as compared with the conventional cutting method using the temperature difference due to the heating operation and cooling operation.

[REPRESENTATIVE FIGURE]

FIG. 2

[SPECIFICATION]

[TITLE OF THE INVENTION]

LIQUID CRYSTAL DISPLAY AND TABLET PC HAVING THE SAME

[BRIEF EXPLANATION OF THE DRAWINGS]

FIG. 1 is a view of a conventional apparatus for cutting a glass substrate using a laser beam.

FIG. 2 is a view showing a cutting mechanism of an apparatus for cutting the glass substrate according to one preferred embodiment of the present invention.

FIG. 3 is a view showing a property of a 4th high frequency YAG laser used in an embodiment of the present invention.

FIG. 4 is a cross-sectional view of crack shapes formed on the glass motherboard by a 3rd high frequency YAG laser and a 4th high frequency YAG laser.

FIG. 5 is a graph showing a transmittance of the 3rd high frequency YAG laser and the 4th high frequency YAG laser with respect to the glass.

<EXPLANATION ON CHIEF REFERENCE NUMERALS OF DRAWINGS >

100: glass mother substrate

110: first laser beam generating member 120: first laser beam

130: second laser beam generating member 140: second laser beam

150: cutting path 160: scribe line

170,180: crack 200: convex lens

[DETAILED DESCRIPTION OF THE INVENTION]

[PURPOSE OF THE INVENTION]

[THE ART TO WHICH THE INVENTION PERTAINS AND THE PRIOR ART]

The present invention relates to a method and apparatus for cutting a non-metallic substrate, by which the non-metallic substrate formed of a non-metal material such as glass and silicon is precisely separated into a plurality of small pieces, and more particularly, to a method and apparatus for cutting the non-metallic substrate, in which the non-metallic substrate formed of the glass and the silicon is completely cut using only scribing laser beam and breaking laser beam without a cooling device.

In recent years, the semiconductor industry, which fabricates a high-integrated and high-performance semiconductor product, has been steady developed according to the development of a semiconductor thin film processing technique. The semiconductor product has a few to a few tens of million semiconductor devices which are integrated on a high-purity substrate called a "wafer" made of single crystalline silicon as one of non-metal materials, by the semiconductor thin film processing technique. The semiconductor product serves to store data in digital form or quickly operate the stored data.

Further, as one of the semiconductor industry applications, a liquid crystal display (LCD) for displaying an analog video signal processed by a data processing unit into digital form has been rapidly developed. In the LCD, liquid crystal is injected between two transparent substrates. A voltage is applied to a certain molecular alignment of the liquid crystal to transform the molecular

alignment into other molecular alignment. The optical property such as double refractivity, optical rotary power, dichroism and light scattering of a liquid crystal cell is changed by the molecular alignment.

The semiconductor product and the LCD have a common feature that they are formed on a non-metallic substrate, i.e., a high-purity silicon substrate and a glass substrate. Disadvantageously the non-metallic substrate is weak for shock and easy to be fragile. However, a plurality of semiconductor chips or LCD unit cells are formed on a sheet of wafer or large-sized glass substrate and then easily separated into each piece.

In case of the semiconductor product, after forming a few to a few hundred semiconductor chips on a sheet of wafer at the same time and cutting into each chip through a separating process, a packaging process of the semiconductor chip is performed to produce the semiconductor produce.

In case of the LCD, after forming at least two or more LCD unit cells on the large-sized glass substrate called motherboard, the LCD unit cell is separated from the motherboard by a separating process, and then assembling process is performed.

At this time, since the separating process belongs to a last step of a production process, a defect in the separating process exerts a bad influence on the productivity and yield of the product. Particularly, in case of the motherboard used for the LCD, since the motherboard has not a crystal structure in the cause of a property of glass, the brittleness of the motherboard is lower than that of a silicon wafer. A fine crack is formed at an edge portion of the motherboard during the separating process. A stress is amplified during a

next process of the motherboard along the crack. Therefore, a defect that an undesired portion of the motherboard is cut is easily generated.

In a conventional art, a diamond blade, of which a circular plate having a desired diameter is studded with fine diamonds at a circumferential surface thereof and rotated at a high speed, is contacted with a “cutting path” to form a scribe line at a desired depth on a surface of the substrate along the cutting path. Then, a physical impact is applied to the substrate so that a crack is propagated along the scribe line to a lower face of the substrate, thereby separating the semiconductor chip or the LCD unit cell from the wafer or the glass motherboard.

When the separating process of the wafer or the glass motherboard is performed using the diamond blade, a cutting margin, a desired surface area for the cutting process, is essentially needed. Therefore, if the cutting process is not precisely performed, the number of the obtained semiconductor chips per a unit wafer decreases.

Particularly, in case of the LCD, since a cut face by the diamond blade is roughly formed, many portions on which stresses are concentrated is formed on the cut face. The stress concentration portion of the curt face is easily broken by only a slight impact applied from an outside, so that a crack or a chipping is vertically generated to the cut face.

Further, in case of using the diamond blade, since so many glass particles are generated, disadvantageously an additional cleaning and drying process is required to remove the glass particles.

Recently, to solve the problem, some cutting methods using a laser

beam are suggested. For example, U.S. Patent No. 4,467,168 entitled "Method of cutting glass with a laser and an article made therewith", U.S. Patent No. 4,682,003 entitled "Laser beam glass cutting" and U.S. Patent No. 5,622,540 entitled "Method of breaking a glass sheet" disclose the above method. Since the cutting method using the laser beam is a non-contact type, the vertical crack formed perpendicularly to the cut face is not generated as compared with the cutting method of a contact type using a friction with the diamond blade.

FIG. 1 is a view of a conventional apparatus for cutting a glass substrate using laser beam.

As shown in FIG. 1, a scribing laser beam 13, for example a CO_2 laser beam having an absorptivity of 95% or more with respect to the glass, is scanned along a cutting path 12 formed on a glass motherboard 10 so as to rapidly heat the cutting path 12 of the motherboard 10.

Then, a cooling fluid beam 14 having a remarkably lower temperature than the heating temperature of the motherboard 10 is applied onto the rapidly heated cutting path 12. Accordingly, while the glass motherboard 10 is rapidly cooled, a crack is generated on a surface of the motherboard 10 to a desired depth to generate a scribe line 15. At this time, the cooling fluid beam 14 may be positioned to be apart from the scribing laser beam 13 at a desired distance or adjacent to the scribing laser beam 13. Otherwise, the cooling fluid beam 14 may be positioned at an inner portion of the scribing laser beam 13.

Subsequently, a braking laser beam such as the CO_2 laser beam is linearly scanned along the scribe line 15 to heat the scribe line rapidly. Thus, a strong tensile force is generated at the scribe line 15, so that the glass

motherboard is completely cut off along the scribe line 15. At this time, the braking laser beam is symmetrically applied with respect to the scribe line 15 to heat both sides of the scribe line 15 rapidly.

The conventional laser cutting apparatus, as described above, is mainly comprised of a laser beam generating portion and a cooling portion so as to heat a non-metallic substrate such as the glass having a low thermal conductivity using the laser beam and then rapidly cool the heated portion of the non-metallic substrate. Therefore, a thermal stress is propagated to a heat moving direction, so that the substrate is cut. However, in the conventional cutting apparatus, since the substrate has to be cooled rapidly using a cooling material in gaseous or liquid state after being scanned by the scribing laser so that a sudden change in temperature is occurred, increasing a cutting speed of the substrate is limited.

In order to cut the glass such as Borosilicate glass (BSG) having a thermal conductivity of 0.36kcal/mh° C (in case of a metal, the thermal conductivity is 57kcal/mh° C), the laser beam should be condensed. However, since laser beam energy applied to each unit surface area is inversely proportional to the cutting speed, an increasing the cutting speed causes the laser beam energy applied to each unit surface area to be low, even if the laser beam is condensed. Therefore, the substrate may be not fully cut. Accordingly, the cutting method using the laser beam is inferior with respect to the cutting speed as compared with the conventional mechanical cutting method in which the cutting speed is controlled by increasing a mechanical speed.

Further, since the propagating method of the thermal stress has to

generate a micro crack at an early stage of the cutting process, an initial crack should be generated at an initial cutting point by a physical force except the scribing laser beam such as the CO_2 laser beam, or by a laser beam based on an impact energy such as YAG. Therefore, a fabricating cost is disadvantageously increased, because the cutting apparatus is provided with total three laser generating portions such as the laser for generating the initial crack, the scribing laser and the breaking laser. Moreover, if a laser head is moved by a repeat operation of the cutting equipment, the initial crack is inconsistent with the scribe line. Therefore, the cutting process has a defect that a cut line is irregularly formed at a starting portion of the substrate.

In addition, in the conventional cutting method using the laser beam, since the cooling material such as water, dry ice, helium gas, etc., is positively necessary, a contamination problem due to a cooling by-product may be occurred. That is, in case of the glass motherboard of which a cut piece is used in the LCD, the remaining cooling material is introduced to a liquid crystal injecting port after the cutting operation, thereby generating a defect in a liquid crystal injecting process. Therefore, a further process is essentially required to remove the remaining cooling material completely after completion of the cutting operation. If a gas is used as the cooling material, since the gas has a lower density than a liquid material, the gas should have lower temperature than a liquid cooling material to increase cooling efficiency. However, if the temperature of the gas is lower than the periphery, the temperature of the periphery is quickly lowered during the cutting operation, so that moisture component at the periphery is condensed. Thus, a moisture material is

generated at the periphery after the cutting operation, thereby generating the defect in the cutting process.

[TECHNICAL OBJECT OF THE INVENTION]

Therefore, it is an object of the present invention to provide a method of cutting a non-metallic substrate made of glass or silicon, in which the non-metallic substrate is completely cut by using only a scribing laser beam and breaking laser beam without a cooling device.

It is another object of the present invention to provide an apparatus for cutting a non-metallic substrate, which is proper to perform the cutting method.

[CONTRUCTION AND FUNCTION OF THE INVENTION]

To achieve the aforementioned object of the present invention, there is provided a method of cutting a non-metallic substrate, which comprises the steps of scanning a first laser beam for breaking bonds between molecules of the non-metallic substrate material on a cutting path formed on the non-metallic substrate to form a scribe line having a crack to a desired depth, and scanning a second laser beam along a scanning path of the first laser beam to propagate the crack in a depth direction of the substrate and completely separate the non-metallic substrate.

To achieve another object of the present invention, there is provided an apparatus for cutting a non-metallic substrate, which comprises a first laser beam generating means which generates a first laser beam for breaking bonds between molecules of the non-metallic substrate material so as to heat a cutting path formed on the non-metallic substrate and form a scribe line having a crack to a desired depth, and a second laser beam generating means which

generates a second laser beam for propagating the crack along a scanning path of the first laser beam in a depth direction of the substrate.

According to the present invention as described above, the first laser beam having a wavelength identical with a natural frequency of the non-metallic substrate is used to breaking the molecular bonds of the non-metallic substrate. A scribe line having a narrow and deep crack is formed on the cutting path of the non-metallic substrate, for example a glass, by the first laser beam, e.g., the 4th high frequency YAG laser beam having the wavelength of 266 nm and the absorptivity of 90% and more with respect to the non-metallic substrate. Then, the CO_2 laser beam as the second laser beam is scanned on the scribe line to propagate the crack in the depth direction of the substrate and completely cut the non-metallic substrate.

Accordingly, the cutting apparatus has only a scribing laser (the first laser) and a breaking laser (the second laser) without the cooling device, thereby simplifying a structure thereof and reducing the fabricating cost comparing with a conventional one.

Further, since a cutting speed can be controlled by a speed of the first laser beam, the cutting speed can be increased and controlled with ease as compared with the conventional cutting method using the temperature difference due to the heating and cooling operation.

Moreover, the cooling device is not employed in the cutting apparatus of an embodiment of the present invention, thereby preventing the process defect such as the contamination of the liquid crystal injecting port after the cutting operation.

Now, preferred embodiments of the present invention will be described in detail with reference to the annexed drawings.

FIG. 2 is a view showing a cutting mechanism of an apparatus for cutting a glass substrate according to one preferred embodiment of the present invention.

Referring to FIG. 2, an apparatus for cutting a glass substrate according to one embodiment of the present invention includes a laser beam generating unit for generating a laser beam to heat a cutting path 150 of a glass mother substrate 100, and a conveying unit (not shown) for conveying the laser beam generating unit to move relative to the glass motherboard 100.

The laser beam generating unit includes a first laser beam generating member 110 for providing a first laser beam 120 to heat the cutting path 150 and form a scribe line 160 having a crack to a desired depth and a second laser beam generating member 130 for providing a second laser beam 140 to propagate the crack along a scanning path of the first laser beam 120 in a depth direction of the substrate 100.

The first laser beam 120 has a wavelength identical to an inherent frequency of the glass to break molecular bonds between glass molecules of the glass mother substrate 100. The first laser beam heats the cutting path 150 of the glass mother substrate 100 to generate the crack to a desired depth from the substrate surface of the cutting path 150 and form the scribe line 160. Preferably, the first laser beam 120 is formed by a 4th high frequency YAG (yttrium aluminum garnet) laser having an oscillating wavelength of 166nm and an absorptivity of 90% or more with respect to the glass. As having a

wavelength identical to the inherent frequency of the glass mother substrate 100, the 4th high frequency YAG laser beam breaks the molecular bonds between the molecules of the glass mother substrate 100 and generates a surface crack (referring to FIG. 4, a reference numeral 180) with respect to all of the scribe lines 160.

The YAG laser is a typical solid-state laser like a ruby laser and it has a chemical composition of $Nd:Y_3Al_5O_{12}$ in which Nd^{3+} ion of about 1% is contained in YAG crystal instead of Y^{3+} ion to generate a near infrared wavelength. The YAG laser can be converted into a laser beam of a high frequency by a high frequency converter and thereby a 2nd high frequency YAG laser having a wavelength of 532 nm, a 3rd high frequency YAG laser of having a wavelength of 355 nm and a 4th high frequency YAG laser having a wavelength of 266 nm are obtained.

FIG. 3 is a view showing characteristics of a 4th high frequency YAG laser used in the present invention.

Referring to FIG. 3, a spot size "d" of the 4th high frequency YAG laser beam that is incident through a convex lens 200 can be calculated by a following equation:

$$d = \frac{4f\lambda M^2}{\pi D},$$

where "f" is a focal distance of the lens, "8" is a wavelength of the laser beam, M is a material constant which is dependent on a kind of the laser and D is an output width of the laser beam.

As shown in the above equation, since the spot size "d" is in proportion to the wavelength of the laser beam, the shorter the wavelength is, the smaller the spot size is, therefore, the shorter the wavelength is, the higher a degree of the beam intensity is. The 3rd high frequency YAG laser beam used as the laser beam for generating an initial crack in the conventional laser cutting apparatus has the wavelength of 355 nm, which is longer than that of the 4th high frequency YAG laser beam used in a preferred embodiment of the present invention, and the spot size of 25 μm.

On the contrary, since the 4th high frequency YAG laser used in a preferred embodiment of the present invention has the wavelength of 266 nm shorter than that of the 3rd high frequency YAG laser, the spot size of the 4th high frequency YAG laser becomes 10 μm, which is smaller than the spot size of the 3rd high frequency YAG laser.

In order to increase a scribing accuracy, preferably the condensed laser beam has a smaller diameter. Thus, as shown in FIG. 4, since the spot size of the 4th high frequency YAG laser beam is smaller than that of the 3rd high frequency YAG laser beam, a contact surface area between the glass mother substrate 100 and the laser beam is reduced to generate a sharp and deep crack. That is, a crack 170 caused by the 3rd high frequency YAG laser beam having the spot size of about 25 μm is widely and shallowly formed on the glass mother substrate 100. However, a crack 180 caused by the 4th high frequency YAG laser beam having the spot size of about 10 μm is formed sharp and deeply. Thus, an occurrence of a fine crack perpendicular to the cutting path 150 is prevented, thereby improving the quality of a cut face after the

cutting process.

FIG. 5 is a graph showing a transmittance of the 3rd high frequency YAG laser and the 4th high frequency YAG laser (having thickness of 0.7 mm and 1.1 mm) with respect to the glass. In FIG. 5, a latitudinal axis of the graph is a wavelength of the laser beam and a longitudinal axis is a transmission of the laser beam.

Referring to FIG. 5, since the 3rd high frequency YAG laser used in a conventional laser cutting apparatus has a transmission of about 85% with respect to the glass of 0.7 mm and about 80% with respect to the glass of 1.1 mm, the YAG laser has a low absorptivity of about 10% to 15%. On the contrary, since the 4th high frequency YAG laser used in a preferred embodiment of the present invention has a transmittance of about 5% with respect to the glass of 0.7 mm and about 1% with respect to the glass of 1.1 mm, the YAG laser used in a preferred embodiment of the present invention has a high absorptivity of about 90 to 97%.

Therefore, the scribing on the glass mother substrate 100 by the 4th high frequency YAG laser beam makes the scribe line 160 formed sharp and deeply due to the high absorptivity and also a scribing speed increased. For example, when cutting an LCD panel of the glass having the thickness of 0.7 mm by the laser cutting apparatus according to an embodiment of the present invention, the speed for full cutting can be increased to 400 mm/sec. Further, since cooling means is not used in the cutting apparatus, the cutting speed can be controlled just by the speed of the first laser beam 120. Therefore, the cutting speed is facilely controlled when compared with that of the conventional

cutting method using a temperature difference by a rapid heating operation and a rapid cooling operation.

The second laser beam 140, which is a high power laser beam like the CO_2 laser beam, has an elliptical beam pattern having desired short and long axes and is scanned on the glass mother substrate 100 so that the long axis of the pattern is aligned with the cutting path 150. The second laser beam 140 is apart from the first laser beam 120 at a desired distance and scanned on the glass substrate 100 along a scanning path of the first laser beam 120. Preferably, the second laser beam 140 is scanned on the scribe line 160 that is formed on the cutting path of the glass mother substrate 100 by the first laser beam 120. At this time, if the scribe line 160 is heated over a fusing point of the glass, a portion, in which the crack is generated, is junctioned again. Therefore, the second laser beam 140 has to be scanned at the same temperature as or a lower temperature than the fusing point of the glass.

Further, referring to FIG. 2, the second laser beam 140 has a width (x_2: length of the short axis) wider than that (x_1: length of the short axis) of the first laser beam 120. The second laser beam 140 is scanned so as to have a depth shallower than that of the first laser beam 120. Here, the depth of the laser beam means the intensity of the laser beam per unit surface area.

The first laser beam 120 has to be scanned as narrow and deep as possible to form the crack on the cutting path 150 of the glass mother substrate 100. On the other side, since the second laser beam 140 is scanned to completely cut the glass mother substrate 100 along the cutting path 150, the second laser beam 140 has to be scanned more widely and shallowly than the

first laser beam 120 so as to prevent an unnecessary crack from generating on the glass mother substrate 100 except the cutting path 150.

A beam profile of the second laser beam 140 can be transformed through a cylindrical lens in which a concave lens and a convex lens are combined. That is, in case of using the cylindrical lens of which an upper face is formed as the concave lens and a lower face is formed as the convex lens, if a spot-shaped laser beam is incident to the concave lens, the laser beam is transformed from the spot shape into an elongated ellipse shape having the short and long axes. If the transformed laser beam is passed through the convex lens, the short axis is more shortened to form a more elongated ellipse shape having the elongated long axis compared with its short axis.

According to the laser cutting apparatus of an embodiment of the present invention as described above, the cutting apparatus comprises the scribing laser (the first laser) and the breaking laser (the second laser) without a cooling device, thereby simplifying the structure thereof and reducing a fabricating cost as compared with the conventional laser cutting apparatus. Further, the cutting apparatus of an embodiment of the present invention does not employ the cooling device, thereby preventing a process defect such as contamination of a liquid crystal injecting port after the cutting operation.

Now, a method of cutting the glass mother substrate 100 using the cutting apparatus shown in FIG. 2 is described more fully.

First, the first laser beam 120 is scanned along the cutting path 150 set up on the glass mother substrate 100 to form the cutting path 150. Since the first laser beam 120 has the same wavelength as the natural frequency of the

glass mother substrate 100, the first laser beam 120 breaks the molecular bonds of the glass mother substrate 100 to generate the narrow and deep crack on a surface of the cutting path 150. Therefore, the scribe line 160 having the crack is formed along the cutting path 150 in a desired depth.

While the first laser beam 120 is continuously advanced along the cutting path 150, the second laser beam 140 is scanned along a scanning path of the first laser beam 120 to rapidly heat the scribe line 160. That is, the second laser beam 140 is directly scanned on the scribe line 160.

Then, thermal gradient is rapidly generated only in a depth direction of the glass mother substrate 100. Accordingly, the crack formed on the surface of the scribe line 160 is straight propagated to a lower face of the glass mother substrate 100 to completely separate the glass mother substrate 100.

In the conventional laser cutting apparatus using the cooling device, since the fine crack is formed using the temperature difference due to the rapid heating and the rapid cooling, an object to be cut such as the glass mother substrate has to be locally rapidly heat. Therefore, since heat transfer to a portion that is not heated by the laser beam should be reduced, a thermal conductivity of the object to be cut becomes an important factor and the object to be cut is limited to the glass and a ceramic material having a low thermal conductivity.

On the contrary, according to the cutting apparatus of an embodiment of the present invention, since the crack is directly formed at the object such as the glass mother by the first laser beam such as the 4th high frequency YAG laser beam, the thermal conductivity of the object to be cut is not so important

as compared with the conventional cutting apparatus. Thus, the laser cutting apparatus of an embodiment of the present invention can be applied to the cutting method of a silicon wafer as well as the glass and the ceramic material.

According to an embodiment of the present invention as described above, the first laser beam has a wavelength identical with the natural frequency of the non-metallic substrate (i.e., capable of breaking the molecular bonds of the non-metallic substrate material). The scribe line having the narrow and deep crack is formed on the cutting path of the non-metallic substrate using the first laser beam such as the 4th high frequency YAG laser beam having the wavelength of 266 nm and the absorptivity of 90% and more with respect to the non-metallic substrate. Then, the second laser beam such as the CO_2 laser beam is scanned on the scribe line to propagate the crack in the depth direction of the substrate and completely separate the non-metallic substrate.

Accordingly, the cutting apparatus comprises only the scribing laser (the first laser) and the breaking laser (the second laser) without the cooling device, thereby simplifying the structure thereof and reducing the fabricating cost as compared with the conventional one.

Further, since the cutting speed can be controlled by the speed of the first laser beam, advantageously the cutting speed can be increased as well as the cutting speed can be facilely controlled as compared with the conventional cutting method using the temperature difference due to the heating and cooling operation.

Moreover, the cooling device is not employed in the cutting apparatus of an embodiment of the present invention, thereby preventing the process

defect such as the contamination of the liquid crystal injecting port after the cutting operation.

While the present invention has been described in detail, it should be understood that various changes, substitutions and alterations could be made hereto without departing from the spirit and scope of the invention as defined by the appended claims.

[CLAIMS]

[CLAIM 1]

A method of cutting a non-metallic substrate, comprising the steps of:

scanning a first laser beam for breaking molecular bonds of the non-metallic substrate material on a cutting path formed on the non-metallic substrate to form a scribe line having a crack to a desired depth; and

scanning a second laser beam along a scanning path of the first laser beam to propagate the crack in a depth direction of the substrate and completely separate the non-metallic substrate.

[CLAIM 2]

The method of claim 1, wherein the first laser beam has a wavelength having an absorptivity of 90% or more with respect to the non-metallic substrate.

[CLAIM 3]

The method of claim 2, wherein the non-metallic substrate is a glass, and the first laser beam is a 4th high frequency YAG laser beam having a wavelength of 266 nm.

[CLAIM 4]

The method of claim 1, wherein the first laser beam is scanned from a starting point of the cutting path to an end point of the cutting path.

[CLAIM 5]

The method of claim 1, wherein the second laser beam is a CO_2 laser beam.

[CLAIM 6]

The method of claim 1, wherein the first laser beam has a width less than that of the second laser beam.

[CLAIM 7]

The method of claim 1, wherein the second laser beam is directly scanned onto the scribe line.

[CLAIM 8]

An apparatus for cutting a non-metallic substrate, comprising:

first laser beam generating means which generates a first laser beam for breaking molecular bonds of the non-metallic substrate material so as to heat a cutting path formed on the non-metallic substrate and form a scribe line having a crack in a desired depth; and

second laser beam generating means which generates a second laser beam for propagating the crack along a scanning path of the first laser beam in a depth direction of the substrate.

[CLAIM 9]

The apparatus of claim 8, wherein the first laser beam has a wavelength having an absorptivity of 90% or more with respect to the non-metallic substrate.

[CLAIM 10]

The apparatus of claim 9, wherein the first laser beam is a 4th high frequency YAG laser beam having an oscillation wavelength of 266 nm.

[CLAIM 11]

The apparatus of claim 8, wherein the second laser beam is a CO_2 laser beam.

[CLAIM 12]

The apparatus of claim 8, wherein the first laser beam has a width less than that of the second laser beam.

[DRAWING]

FIG. 1
(PRIOR ART)

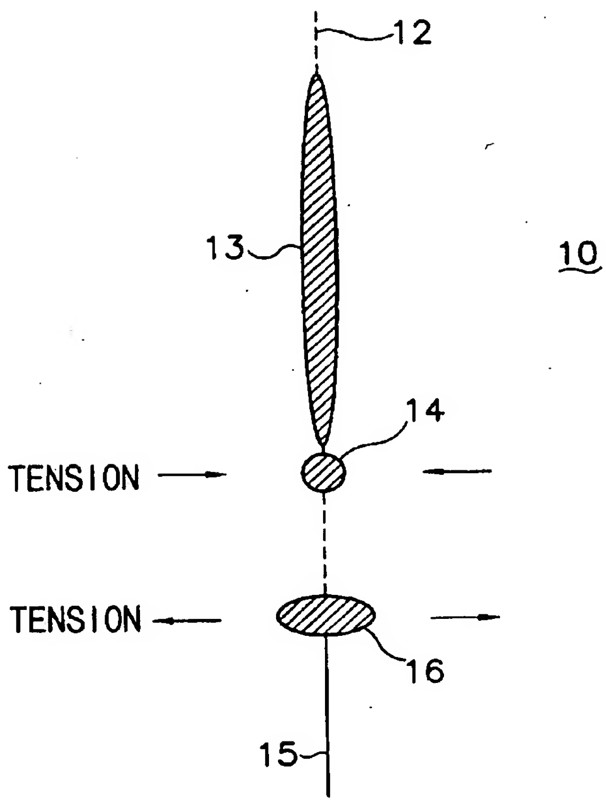


FIG. 2

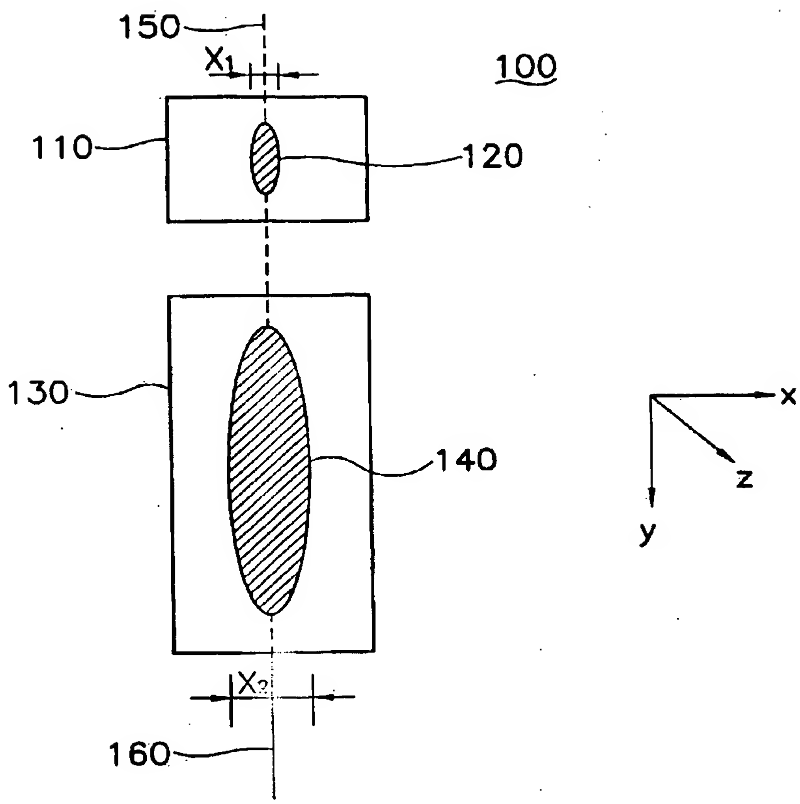


FIG. 3

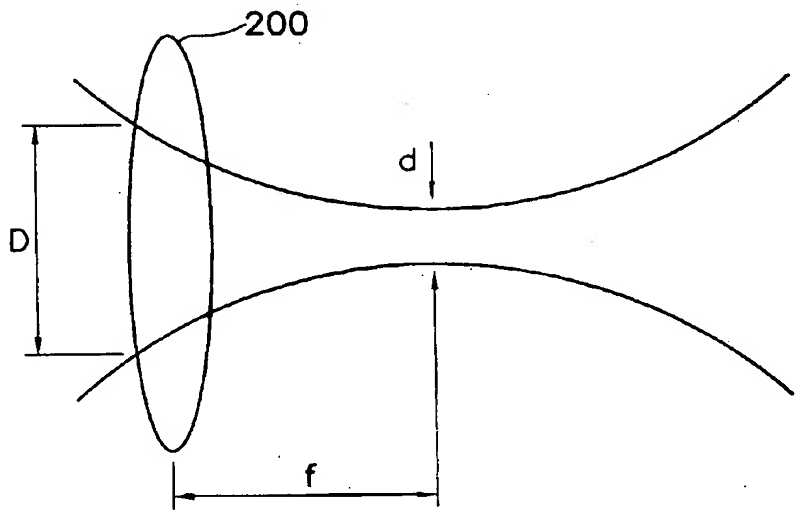


FIG. 4

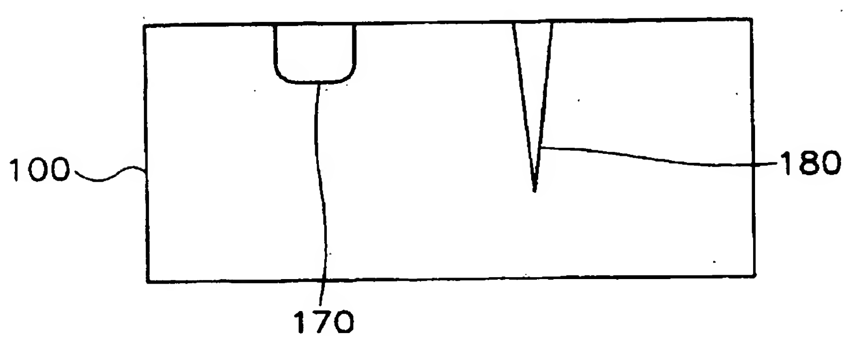
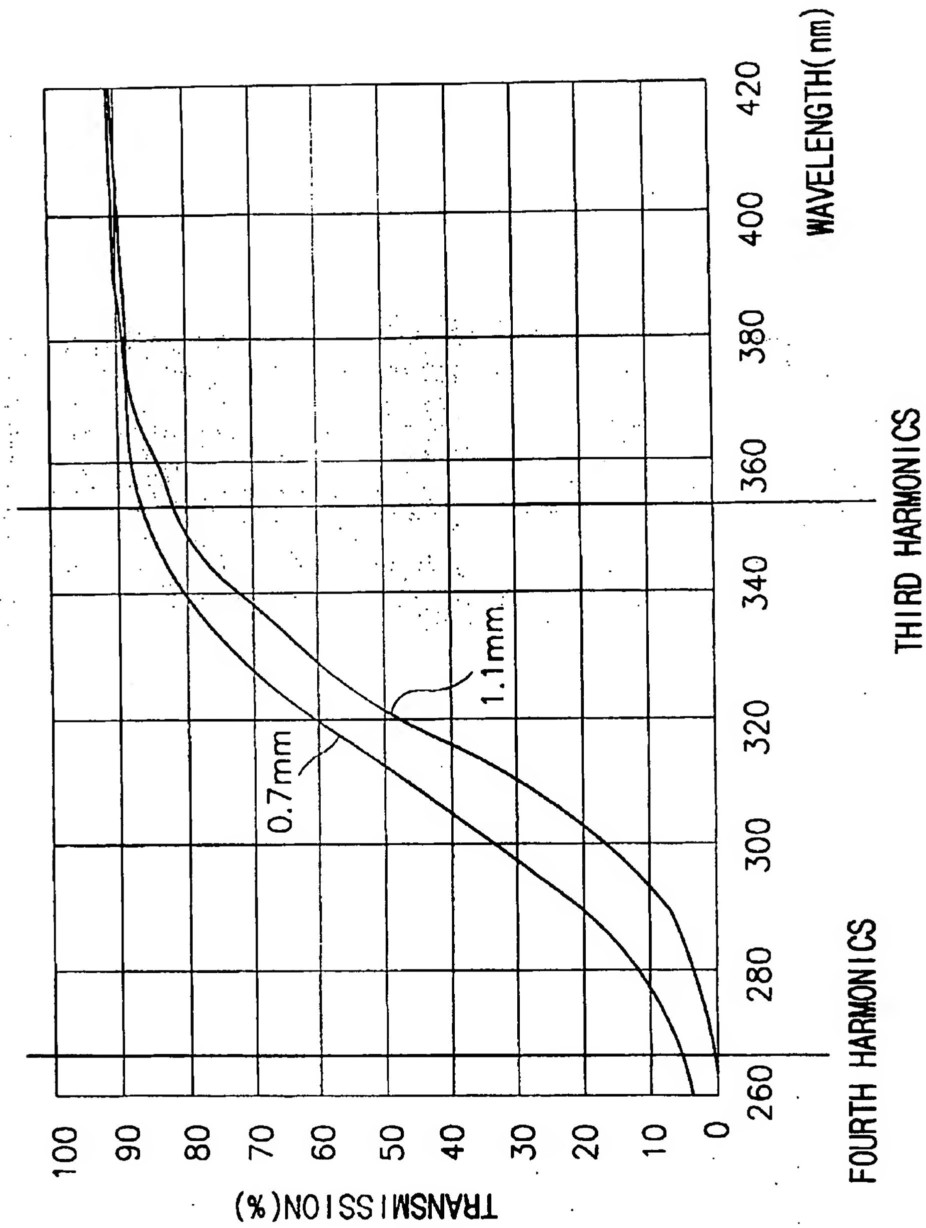


FIG. 5



TRANSMISSION(%)
100
90
80
70
60
50
40
30
20
10
0
260
280
300
320
340
360
380
400
420
WAVELENGTH(nm)
0.7mm
1.1mm
FOURTH HARMONICS
THIRD HARMONICS